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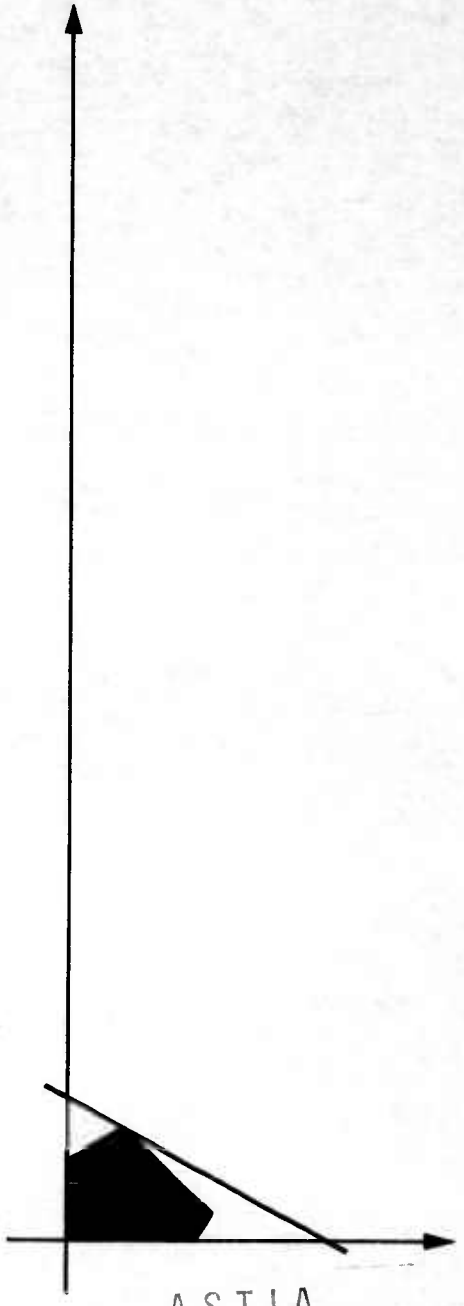
by

William S. Jewell



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William S. Jewell
Operations Research Center
University of California, Berkeley

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DIAGNOSTICIANS IN AUTOMATED PROCESSES*

Mr. Chairman, Gentlemen:

I think we will all agree that automation is here to stay. With the advent of new technologies and the availability of new techniques for making decisions has come growth of the automated process; from simple closed-loop control circuits we have advanced to the modern refinery, computer-controlled from start to finish. You, better than I, can predict some of the miracles in process automation which are just ahead: automated assembly lines, traffic control systems, integrated plant-warehouse inventory control systems, and so forth.

It is the role of the University to assess, in so far as possible, the effect of these technological revolutions upon the training and development of men. In particular, we must strive to train engineers and scientists who will not be obsolete in ten or twenty years, but who will have the talent and skills needed then.

Today I would like to discuss two needs in the development of trained manpower, and indicate what I feel is an area of weakness in the planning for full automation.

The Need for Analytical Training

The first need is for people trained in the analysis and development of systems and technologies -- the chemist, physicist, instrumentation

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* This report is a revised version of an invited talk of the same name presented at the Sixteenth Annual Instrument Society of America Conference, in Los Angeles, California on September 11-15, 1961.

engineer, computer scientist, operations researcher, management scientist, and so on. The need for people trained in these specialties is obvious. In spite of the continuing cry that good analytical talent is lacking, I feel that the demand is being met, and that such men are now being trained in our universities, and in some of our industries.

For example, at the University of California, Berkeley, we have decided that students in Industrial Engineering must have a substantial strengthening of their analytic base, and a broadening of their fundamental courses in order to prepare for the age of automation. One way this is being done is through the introduction of an operations research program to train engineers and scientists in the fundamentals of decision making. At the same time a substantial revamping is being made of our administrative engineering program to provide technical specialist-managers for industry and government. In both programs we find:

1. More mathematics and statistics

   All undergraduates in industrial engineering must have a year of probability and statistics. Graduate students are encouraged to elect a mathematics or statistics minor.

2. More courses in operations research and systems analysis

   All undergraduates in industrial engineering take at least a one-year introductory course in operations research. In addition, all graduate students must take at least another year in advanced decision-making techniques and in the application and synthesis of these techniques to applied operational areas.

3. Increasing emphasis on fundamentals

   Both programs find increasing emphasis on economics, mathematics, and statistics, and on basic areas of engineering science.

4. Increasing exposure to the use of digital computer techniques

   All analytic courses stress the importance of machine-aided analysis and special courses are being developed in the application of computers to operations research problems.

Similar educational programs are being developed throughout the United States, and many industries are retraining their own personnal or sending them back to school. I think the need for analytic training is being met.

The Need for Diagnostic Training

But it is a second need which I wish to analyse today -- the need for trained diagnosticians for automated processes. What I mean by "diagnostician" is, a highly skilled "repairman" whose primary purpose will be the diagnosis and correction of failures and malfunctions of large automated systems.

Why do we need technical people trained for this new role? The first reason is that of the growing complexity and size of our automated operations. Instead of the simple controlling device, we now have large and complicated systems, monitored and controlled by a central computer and a host of special input-output devices. More complexity means more chance for failure.

The second reason for requiring highly skilled training for diagnosticians is that the control systems of the future will be largely analytic systems in which large amounts of numerical data will be monitored, manipulated, stored, and used for control. Thus, the inner workings of future systems will be arithmetic as well as mechanical or electronic.

There will also be more emphasis on random elements and uncertain behavior of the system. As the size and complexity of an automatic system grows, man's ability to predict the unique outcomes of all relationships between the many internal and external variables decreases, and the isolation and treatment of malfunctions becomes increasingly "ill-defined."

Why not use the same engineer-scientists who designed the systems to function as the repairmen? Why train new specialists? I think most of you in the defense industries can best answer that question. First, the original designers of automated systems have a distressing tendency to leave a company for greener pastures after a system has been designed and installed. Their memory (or desire to remember) becomes weaker the longer the system is in operation. Secondly, many firms have an uncontrollable desire to modify, or "add-on" to a large system -- sometimes independently of the real need for such custom modifications. Thus, the detection of trouble in an automated system is, and will continue to be, a "who-dun-it?" -- in need of a specialist.

Finally, the main reason for installation of an automated operation is economic -- a desire for optimal operation, not just feasible operation. By the same token, diagnosis and correction of malfunctions becomes vitally important in terms of "down-time." Compare, for instance, the cost of down-time for an automatic milling machine versus the cost if a refinery operation were shut down for the same time!

Of course, standby systems and redundant configurations eliminate much of the worry associated with total breakdown; but, the system must now be larger and more complex, with increased problems of maintenance, malfunction detection, diagnosis, and repair.

I think a case has been made for the training of a highly skilled, scientific diagnostician for behind-the-scenes work on the automated systems of the future.

The Training of Diagnosticians

How are we doing in the training of these diagnosticians for the future? Not too well at present. Part of the problem is that current needs of industry in this area, while growing, are still highly specialized to a certain installation, a certain type of computer, etc. This will change with time, and we may expect to see an eventual common area of knowledge in automatic diagnostics.

In the Department of Industrial Engineering at the University of California we are beginning to emphasize diagnostic training in several ways. The analytic strengthening of our basic programs has already been mentioned.

Secondly, we are placing more emphasis on problems of scheduling, replacement theory, and preventive maintenance. The re-optimization of systems when parameters change, and the influence of uncertainty, are treated in all of our courses on methods of operations research. Applied courses are planned in the special problems of service systems.

In the area of human factors, there is less emphasis on man as an individual worker, and increasing investigation of man as an estimator in automatic systems. While we cannot yet define the ultimate function of man in systems of the future, it is becoming increasingly clear that many traditional roles of the human being are becoming obsolete.

Of course, increasing analysis must be placed on the uses (and abuses) of computers and control systems. Not only must a man have knowledge of the technology of computation, but he must also be aware of how it can influence or supplement his ability to make decisions.

We feel also that it is necessary to train people who are flexible in their ability to apply fundamentals to the varied problems which will arise in complex systems. Part of this training in synthesis will be in a thesis or graduate project, or in applied research on various projects at the Operations Research Center of the University of California, Berkeley.

However, there is still a lot of work to be done in developing the training of diagnosticians. And we certainly are open to suggestions from industry on needs for the coming years.

A Charge to Members of the ISA

I would like to close with a charge to members of the Instrument Society of America, since I feel that much can be done to develop diagnostic instrumentation for the automated systems of the future.

Two ways suggest themselves:

1. By placing more emphasis on predictive, preventive instrumentation, rather than on static, status-reporting instrumentation. Thus, the instrumentation of the future should have a prognostic function, reporting, for example, on deterioration of system reliability, or estimating the distribution of time until a certain sub-system will breakdown. The increased use of time-sharing digital techniques will make possible the continued monitoring of performance of all parts of a system in this manner.

2. By developing more built-in diagnostic functions and instrumentation for failure and malfunction analysis. Most modern computers, for instance, have a wide range of diagnostic and "post-mortem" programs designed to isolate both the electronic and arithmetic (or logical) causes

of failure. This trend should be carried forth in all aspects of the design of automated systems in order to give instantaneous indication of trouble origin, and automatic initiation of emergency modes of operation.

In conclusion, I think the developments in automation of the decade will be impressive to watch and challenging to work in. I hope you will agree with me that we will have increasing need for well-trained diagnosticians in automated processes.

Thank you.

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